
Design of a Free-running, 1/30th Froude Scaled Model Destroyer for In- situ Hydrodynamic Flow Visualization



LT Dave Cope
3 May 2012

Advised by
Prof Chrys Chrysostomidis
Dr. Brenden Epps

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 03 MAY 2012		2. REPORT TYPE		3. DATES COVERED 00-00-2012 to 00-00-2012	
4. TITLE AND SUBTITLE Design of a Free-running, 1/30th Froude Scaled Model Destroyer for In-situ Hydrodynamic Flow Visualization (BRIEFING CHARTS)				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Massachusetts Institute of Technology, Naval Construction & Engineering Program, Department of Mechanical Engineering, Cambridge, MA, 02139				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 11	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Agenda

- **Project Goal**
- **Background**
- **Design**
- **Current Status**
- **Remarks**

Project Goal

- Design and build a **1/30th Froude scaled**, free-running model of the David Taylor Model Basin **5415** hull for **hydrodynamic visualization** and **crashback maneuver** testing and serve as a **flexible test platform** for future research within the MIT Ocean Engineering department.

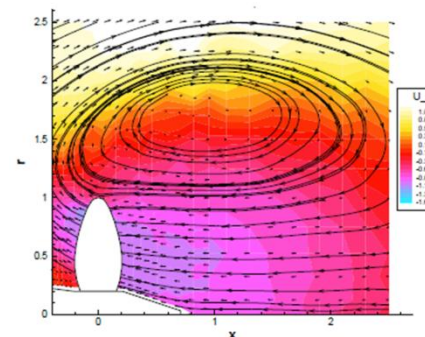
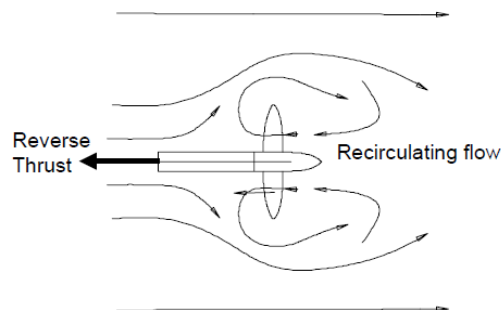
Scale (λ)	30	
Main Particulars		
LWL	15.6	[ft]
LOA	16.8	[ft]
BWL	2.1	[ft]
T	0.67	[ft]
Displacement	10.83	[ft ³]
Wetted Surface	36.64	[ft ²]
C_B	0.507	
C_M	0.821	
Design Froude Number	0.28	
Turbulence Stimulation	No	

- **Crashback Maneuver**

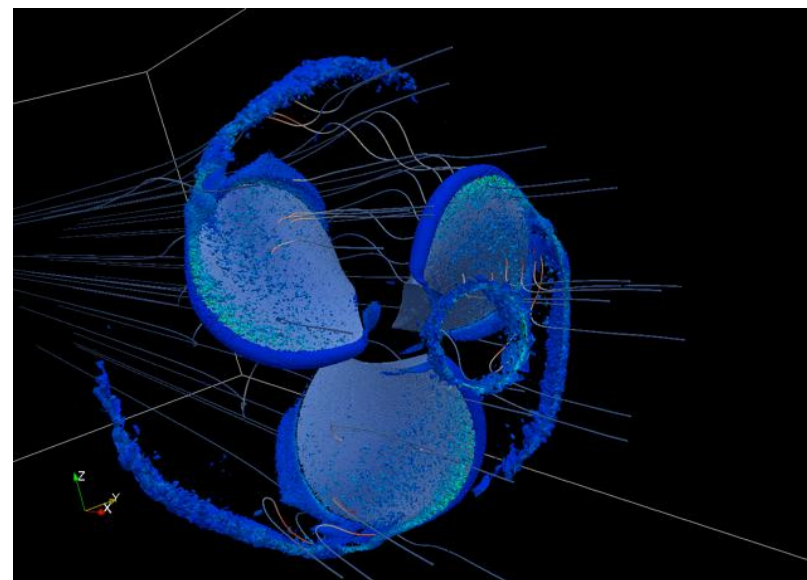
- Unsteady flow
- Oscillating vortex ring
- Leading edge flow separation
- Extreme blade loading
 - 280% root bending
 - 215% torque
 - 188% thrust

- **CFD efforts**

- LES at static advance coeff
- Immersed boundary methods

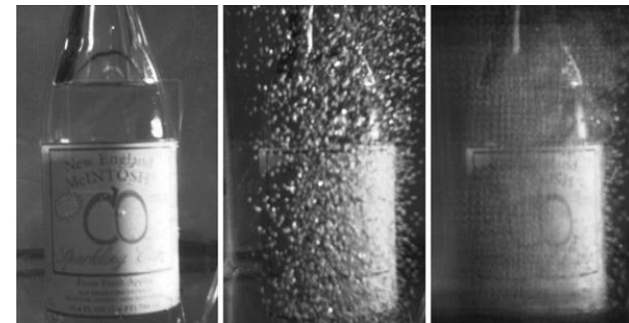
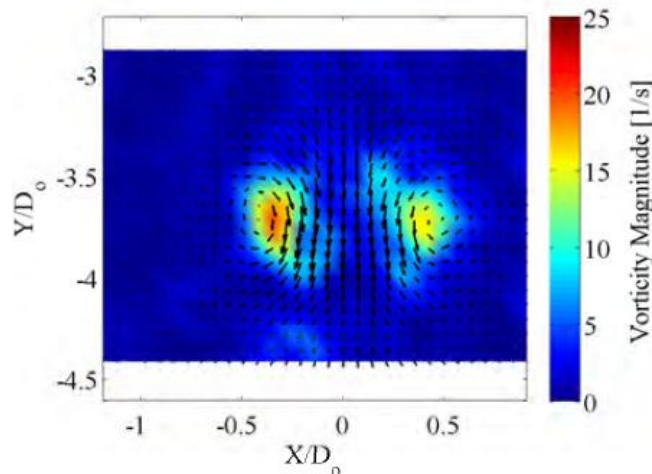
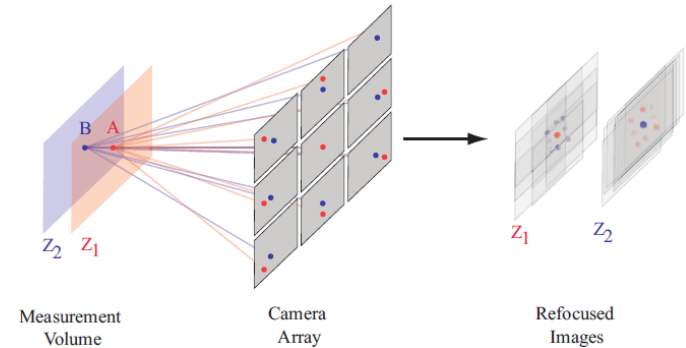


Jessup, et al



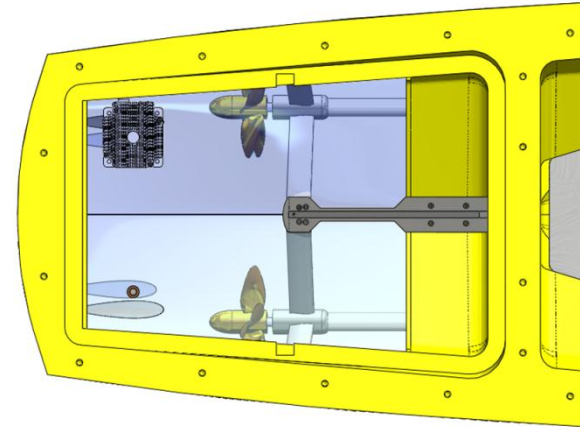
Epps, et al

- **SAPIV**
 - Applied by Belden
 - Synthetic Aperture
 - Ability to 3D image large volume with optical occlusions
 - Successfully applied to imaging a vortex ring



(a) original object with no bubbles (b) object in bubbly flow (c) SA refocused image

- Modified DTMB 5415 Hull
 - Solidworks modeling
 - User inputs
 - Increased freeboard
 - Stern window
 - Ship Spec
- Hull Construction
 - Competitive bidding process
 - Winner: Maritime Applied Physics Corporation of Baltimore, MD

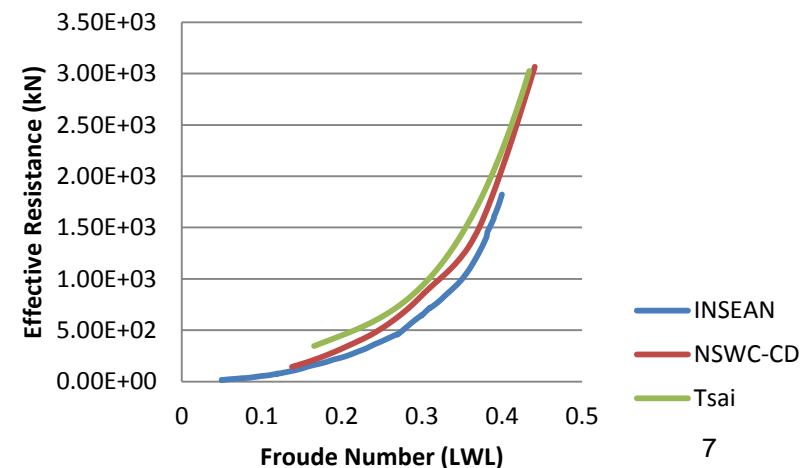


- Appendages
 - Built in-house to reduce costs
 - No bilge keels
 - Rudders based on NACA 0018
 - 6.8 inch 4381 Propellers
 - Plating
 - $R_n \approx 5.38 \times 10^5$



5415 Powering

Blade Material	Young's Modulus (E)	2 nd Moment of Area (J)	EJ	Relative Stiffness
ABS FDM	1.45×10^5 [psi]	$7.77\text{E-}04$ [in ⁴]	$1.13\text{E+}02$ [lb-in ²]	1
Cu+Ni Plated ABS	3.0×10^7 [psi]	$8.74\text{E-}04$ [in ⁴]	$3.01\text{E+}03$ [lb-in ²]	27
Solid Aluminum	1.0×10^7 [psi]	$7.77\text{E-}04$ [in ⁴]	$7.77\text{E+}03$ [lb-in ²]	69



- **Propulsion**
 - 2 x Kollmorgen AKM Brushless DC motors
 - 2.02 N-m continuous torque
- **Maneuvering**
 - 2 x IMS Mdrive23 Steppers
- **Control**
 - 2 x Kollmorgen AKD 120 VAC drives
 - Baldor e100 multi-axis, PID
- **Communications**
 - 802.11 g/n, high gain ant
- **Microstrain IMU**
 - GPS-aided accelerometer/magnetometer



Delivery



Current Status

- **Behind schedule, over weight...but under budget**
- **Model repaired as of 27 April**
- **Test bench setup complete, PID controller tuned and ready for install**
- **Expect open water trials and propulsion tuning by end of May**

Acknowledgements

- **Prof Chryssostomidis**
- **Dr. Brenden Epps (Prof SEL)**
- **Mike Soroka**
- **MAPC**
 - Paul Dillingham
 - Kyle Moseson